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Population Analysis of Douglas-fir Tussock Moth in Northeastern Oregon and Southeastern Washington, 1999

Report No. BMPMSC-00-09

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EXECUTIVE SUMMARY

Douglas-fir tussock moth is a native forest insect which defoliates conifer host trees during periodic outbreaks in western North America. During the caterpillar stage, tussock moths damage trees by feeding on the foliage of Douglas-fir, grand fir, and white fir throughout its host range. Outbreaks occur at intervals of about 7 to 10 years, and usually last 3 to 4 years. The Blue Mountains are currently entering into an outbreak cycle of the tussock moth. Damage to trees by larval feeding include crown defoliation, tree mortality, top-kill, stem or top deformities and defect, height and radial growth loss, increased susceptibility to secondary bark beetles and disease, and various effects on forest ecosystems. The management actions to sustain forest ecosystems, restore watersheds, enhance and protect critical species habitat, and provide recreation opportunities for forest visitors can all be greatly influenced by outbreaks of tussock moths and other defoliators.

The U. S. Forest Service, Pacific Northwest Region, has undertaken an environmental analysis to evaluate options for short-term management of the tussock moth outbreak. National Forests throughout the Region having potential risk of developing tussock moth outbreaks have identified and mapped areas of critical resource concern that can be damaged by tussock moth. These include such resources as habitat areas (stream reaches, nest sites, etc.) for federally listed animal species like bull trout and anadromous salmon and steelhead runs, bald eagles and spotted owls; municipal watersheds; designated old-growth areas, late and old structural forests and late successional reserves; residential and administrative sites; campground and recreation areas; and visually sensitive areas. The Malheur, Umatilla, and Wallowa-Whitman National Forests identified a total of 2,667,850 acres of host type that could be affected by tussock moth based on experience from past outbreaks, and a total of 252,090 acres of high value areas (resources under many of the categories listed above).

During the summer and fall of 1999, Forests conducted sampling of the early larval and cocoon stages of tussock moth to analyze current populations and predict the expected population levels in the spring of 2000 on the high value areas they identified. Based on analysis of these samples, several analysis areas are predicted to be in outbreak in 2000. These outbreak areas will result in visible defoliation of host trees and varying levels of resource damage as previously described. Recommendations are made to treat outbreak populations of tussock moth where they are expected to occur in high value areas. These recommendations include aerial treatment with a biological insecticide to partially suppress populations of tussock moth to protect high value areas and reduce the level of defoliation damage to host trees if the outbreak occurs as predicted in the following areas of critical resource concern: Spangler Trail, Big Butte Lookout, and Donaldson Gulch Analysis Areas (Pomeroy Ranger District, Umatilla National Forest); Manilla Springs Analysis Area (Walla Walla Ranger District, Umatilla National Forest); and Clear Creek, East Eagle Creek, Little Eagle Creek, and Little Elk Creek Analysis Areas (Pine Ranger District, Wallowa-Whitman National Forest). In addition, recommendations are made to re-sample the early larval and cocoon stages of the tussock moth during 2000 on all current Analysis Areas to obtain population data to establish the actual tussock moth population status in 2000, and predict the population status for 2001 on these high value areas.

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Introduction

The Douglas-fir tussock moth, *Orgyia pseudotsugata*, is a major defoliator of Douglas-fir and true firs in western North America. Outbreak records from various localities and time periods show that tussock moth outbreaks occur with more or less regularity throughout the insect's range (Clendenen et al. 1978; Harris et al. 1985; Shepherd et al. 1988; and Swetnam et al. 1995). Outbreaks occur on cycles from about 7 to 10 years. The length of time between peaks of the outbreak appears to average about nine years (Shepherd et al. 1988). Most tussock moth outbreaks last about three years. A naturally occurring disease caused by a nucleopolyhedrosis virus (NPV) has been a major factor in the collapse of many tussock moth outbreaks of the past; typically at the beginning of the third year of the outbreak (Wickman et al. 1973).

Tussock moth populations show remarkable synchrony over large regional areas and usually increase region-wide at about the same time. However, anomalies do occur. It is interesting to note, for example, that the 1991-1995 Burns, Oregon outbreak was out of sync with, and delayed by at least a year from, the Pine Ranger District outbreak that was treated with *Bacillus thuringiensis* (*Bt*) in 1991 (see Mason et al. 1998; Scott and Schmitt 1996; USDA 1996).

Tussock moth populations develop largely in place from resident populations which build up slowly over several years before entering the outbreak cycle (Wickman et al. 1973). Once the conditions are right for rapid buildup of populations, the outbreak develops suddenly, typically in an eruptive manner, and often causing unexpected, severe defoliation of host conifer stands (Mason et al. 1998).

The collapse of tussock moth outbreaks, usually in the 3rd or 4th year of outbreak, are also abrupt. Natural disease and other factors help terminate tussock moth outbreaks. Although nucleopolyhedrosis disease (NP; caused by nucleopolyhedrosis virus, NPV) often figures prominently as a mortality factor during many tussock moth epidemics, it is only effective in the larval stage since larvae must ingest the virus polyhedral inclusion bodies (PIB) on contaminated

foliage before the virus can be effective in developing disease in the insect.

Contagion is the means by which the virus spreads through the population (Thompson 1978), usually resulting in several consecutive waves of infection that begin occurring about 2 weeks after initial exposure to the virus (Thompson and Maksymiuk 1978). Once larvae become infected with the virus and die, the insect cuticle becomes flaccid and eventually ruptures, spilling the virus laden content onto the foliage beneath. Other healthy larvae feeding on foliage eventually ingest this virus-contaminated foliage, and in turn die. The first wave of virus infection is followed by two more, with succeeding waves occurring at about 2-week intervals (Thompson and Maksymiuk 1978).

The tussock moth NPV replicates itself by using the DNA in the nucleus of insect cells that become infected. The PIBs of the virus contain complete particles of the virus (called virions). Nucleocapsids (the double-stranded, supercoiled DNA genomes) comprise these virions (Martignoni 1999). The nucleocapsids are released from the PIBs upon ingestion by the insect and infect, initially, the midgut cell nuclei, beginning the first cycle of viral replication which ultimately destroys the cells that are infected (Martignoni 1999). This virus infects only Douglas-fir tussock moth larvae and three other related tussock moths, two of which occur in the West, and the third is an eastern species that does not occur here. The virus does not infect any other insect nor vertebrate animal, including birds, fish, or mammals. The very narrow spectrum of activity and safety of this virus makes it desirable as a biological control agent. The Forest Service has developed and registered it with the U. S. Environmental Protection Agency, in a product called TM BioControl-1, for that purpose.

While the virus targets the larval life stage of tussock moth, other life stages are also vulnerable to various mortality factors, including insect parasitoids and predators, vertebrate predators, starvation, and others (Mason and Wickman 1988). In addition, arboreal spiders are significant predators of tussock moth and other forest defoliators (Mason 1992). Most likely, it is the combined affects of these multiple factors that cause the collapse of most tussock moth outbreaks, rather than any single factor.

Although large tussock moth outbreaks can result in the killing of as much as one-third of the stand, usually in patches of tree mortality, trees that are severely defoliated in other areas can recover rapidly from defoliation damage once the damage subsides (Wickman et al. 1973). Trees weakened by severe defoliation by tussock moth defoliation are often attacked and killed by secondary bark beetles, which can kill large numbers of trees when they increase numbers in this abundant habitat (Wright et al. 1984).

Douglas-fir tussock moth populations are monitored annually throughout the Pacific Northwest Region as part the Douglas-fir Tussock Moth Early Warning Detection System. Sticky traps baited with lures containing the synthetic analog of the natural sex pheromone produced by adult female tussock moths are used to capture and quantify male moths that are attracted to the pheromone in the trap during the late summer and early fall mating season (Daterman et al. 1979). In the Blue Mountains, we have used an average of 25 or more moths per trap as a

threshold indicating that increasing populations could lead to larval populations high enough to cause visible defoliation within the next two summer seasons. This threshold is used to "trigger" additional sampling efforts to quantify and classify the status of tussock moth populations over an analysis area. Recent pheromone trap results have indicated increasing tussock moth populations throughout the Pacific Northwest Region (Ragenovich 1998). Population trends measured in northeastern Oregon and southeastern Washington, and north central and northeastern Washington indicated reasonable probability of visible defoliation from tussock moth occurring in some areas during 1999.

Based on several seasons of high tussock moth pheromone trap counts in the Blue Mountains, we initiated intensive larval population surveys in the spring of 1998 and 1999 following Regional Guidelines for sampling Douglas-fir tussock moth (Sheehan and others 1993). This report summarizes the results of the 1999 Spring tussock moth lower crown early larval sampling and Fall cocoon sampling for all cooperating federal lands in northeastern Oregon and southeastern Washington, including cocoon sampling conducted by Oregon Department of Forestry on selected private lands near Halfway, Oregon in 1999 (data used by permission of Oregon Department of Forestry, Salem, Oregon).

Methodology

Early Larval Sampling

We non-destructively sampled tussock moth larval populations by the lower crown sampling technique described by Mason and Paul (1994). Early larval sampling commenced on June 28, 1999, and proceeded over the next 2 to 3 weeks depending on development stages of larvae. Ideally, we timed sampling to coincide when the majority of larvae were in the first and second instars (L1 and L2), but some larval sampling occurred during later larval stages. Each Ranger District provided crews from their permanent and seasonal staffs to conduct the sampling on their respective Districts.

Sampling areas (analysis areas) were established based on direction from the Regional Office, Pacific Northwest Region, which had begun an environmental analysis in June, 1999 to evaluate options for short-term management of the anticipated tussock moth outbreak. Accordingly, sample plots were located in areas identified by each Ranger District or National Forest as having critical resource concern and needing protection from defoliation. Areas identified for sampling included the habitats for threatened and endangered stocks of anadromous salmon and steelhead, and for certain stream reaches containing bull trout. Additional critical habitat areas in Forests across the Region having tussock moth outbreak potential that would require protection included nesting sites of bald eagles or spotted owls (for those Forests containing owl habitat/populations). Other areas of critical resource protection concern include municipal watersheds, designated old-growth areas, late and old structural forests and late successional reserve areas, residential and administrative sites, campgrounds and recreation sites, and visually sensitive areas (scenic foreground visual resources, scenic by-ways and other travel routes, scenic vistas, etc.).

Approximately 50 tussock moth host trees (Douglas-fir, grand fir, or white fir) were sampled at each sample plot. These trees were selected at random over an area of roughly 2-10 acres, and were required to have branches that could be reached from the ground and contained new (current year) foliage. No distinction was made in the selection of host tree species during the sampling process. Crews sampled one or more plots within or immediately adjacent to an area designated as having a critical resource concern for the District or Forest. The sampling procedure involved rapping three 18-inch branch tips containing new (current year) foliage from each sample tree over a canvas cloth-covered aluminum sampling frame, with a small section of PVC pipe to dislodge larvae (see Paul 1979 for a description and design of the sampling equipment). The numbers of tussock moth larvae from all three branches were counted and recorded for each sample tree, along with the instars that were observed. After recording data on forms provided, the completed data forms were returned to the Service Center Entomologist for analysis and summary.

Prior to commencement of sampling, the Service Center Entomologist for the Blue Mountains Province provided on-the-ground training in the sampling procedure and identification of tussock moth larvae, and larval stages. Crews from Oregon Department of Forestry and Washington Department of Natural Resources also participated in this training so that sampling of state and private lands would be consistent with Forest Service protocols.

Cocoon Sampling

Cocoon sampling in the Blue Mountains commenced on September 7, 1999 and continued in different areas of the Blue Mountains through October 1999. We followed a sampling protocol developed in collaboration with the Regional Office (Ragenovich 1999). Cocoon sampling essentially occurred on the same areas sampled during the early larval stage. In addition, other areas of resource concern adjacent to those sampled during the early larval stage were sampled for cocoons on some of the districts. The sampling intensity varied depending on size of the area identified for sampling: the protocol established 1 plot of 50 trees distributed across the plot site in "sample areas" of 10 acres or less in size; 5 to 30 plots of 20 sample trees per plot distributed across each plot in sample areas of 11 to 1,000 acres in size; and 1 plot of 20 trees per square mile, or for each 1,000 acres, in sample areas of over 1,000 acres in size. In many cases, sampling intensity exceeded the protocol for numbers of trees. Many Ranger Districts sampled 50 trees or more at each cocoon sampling plot. A few Districts sampled less intensively.

The cocoon sampling involved inspecting three 18-inch branch tips from the lower crown of each sample tree and recording the numbers of new cocoons, live cocoons (if crews felt comfortable enough in determining this), and new egg masses for each tree on the forms provided. All completed data forms were returned to the Service Center Entomologist for analysis.

Data Analysis

Tussock moth larval density data obtained on each of the analysis areas were expressed in mean number of larvae per 3-branch sample. These data had to be converted to midcrown densities

and expressed in mean number of larvae per 1,000 square inches of foliated branch area to classify the population status in each analysis area (Mason 1977b). We used the procedure described by Mason (1977a) to estimate midcrown densities from lower crown densities. All data were entered on a PC into a Paradox data table and analyzed and summarized by 1999 early larval population status (see Appendix 1).

Cocoon data were analyzed with a regression equation to predict the 2000 early larval midcrown densities expressed in mean number of larvae per 1,000 square inches of foliated branch area to classify the population status in each analysis area according to the procedure of Mason et al. (1993). All calculations were performed by Paradox database software queries on a PC. Results of the cocoon data analysis, and summaries of predicted early larval densities for Spring 2000 are included in Appendix 2.

The classification of the tussock moth 2000 larval population status predicted from 1999 Fall cocoon samples is based on the following table reproduced from the report by Mason et al. (1993):

Table 1. Relation of estimated cocoon densities in preoutbreak populations of the Douglas-fir tussock moth to predicted larval densities and status in the next generation.

RANGE OF COCOON DENSITIES IN THE LOWER CROWN	PREDICTED LARVAL DENSITIES IN THE MIDCROWN	PREDICTED POPULATION STATUS
---------- *No./1000 square inches* ----------		
<0.01	<2.0	Low density; no defoliation.
0.01-0.30	2.0-20.0	Suboutbreak; little or no visible defoliation.
0.31-0.70	21.0-40.0	Moderate outbreak; defoliation visible on most host trees.
>0.70	>40.0	Severe outbreak; defoliation intense in upper crown of many host trees with some trees completely defoliated.

Results and Discussion

Malheur National Forest

The Malheur National Forest mapped a total of 130,072 acres of tussock moth host-type in "Critical Habitat Areas" (see Malheur National Forest Douglas-fir Tussock Moth public scoping letter, dated July 22, 1999, on file at the Malheur NF, John Day, OR). Analysis of early larval sampling data for the Malheur revealed that 7.7 percent of the total larval sampling plots located within critical habitat areas on the Forest were in **suboutbreak** status (little or no visible

defoliation) in 1999, 33.8 percent of the plots had **low** populations (no defoliation), and 58.5 percent of the plots contained **very low** populations (see Figure 1).

Analysis of Fall cocoon sampling data for the Malheur predicted that 3.1 percent of the total cocoon sampling plots located within critical habitat areas on the Forest would be at **moderate outbreak** (defoliation visible on most host trees) in the early larval stage in the spring of 2000, 25 percent of the plots are predicted to be at **suboutbreak**, and 71.9 percent of the plots are predicted to contain **low** populations of larvae (see Figure 2).

Bear Valley Ranger District

The Bear Valley Ranger District sampled a total of 23 locations (plots) during the Spring 1999 early larval sampling period. These plots represented five general areas of tussock moth host-type having several identified locations within them with resources of concern to the District (see Malheur NF public scoping letter dated July 22, 1999). Of the five analysis areas (1640 Road, Canyon Creek, Deer Creek, Fields Creek, and Starr Ridge) only 1 of the 8 plots established in the Deer Creek Analysis Area, and 4 of 6 plots established in Fields Creek Analysis Area contained larval populations that were currently at suboutbreak levels, and had the potential for going to outbreak the following year (Figure 3). No plots on Bear Valley RD were presently in outbreak. Early larval populations on all the plots located along the 1640 Rd and in the Canyon Creek and Starr Ridge Analysis Areas were either currently low or very low. There seems to be lower probability for these plots to reach outbreak levels in 2000 or beyond based on these data, although the possibility should not be ruled out entirely.

Analysis of the 1999 lower crown cocoon data from the Bear Valley Ranger District predicted that on average, the early larval populations in the Fields Creek Analysis Area would be suboutbreak in Spring 2000 (Table 2). Cocoon populations on one of the Fields Creek Analysis Area plots was high enough that the regression analysis predicted this plot to be in outbreak in 2000 (Appendix 2). This plot represents a very small portion of the entire analysis area and is probably insignificant in terms of the overall impact of tussock moth in this analysis area in 2000. However, given the eruptive nature of tussock moth populations it does merit continued monitoring this year. Other Bear Valley RD analysis areas are predicted to have either suboutbreak or low larval populations in 2000 (see Figure 3). No other analysis areas on the Bear Valley RD contained cocoon populations on any plot that were predicted to be in outbreak in 2000 other than the one plot on the Fields Creek Analysis Area discussed above. However, since sample plots are limited in number, and population estimates are always subject to some sampling error, there is a small possibility that portions of any suboutbreak area could actually have populations of larvae high enough to cause visible defoliation on part of that area in 2000. If tussock moth populations increased to outbreak in 2000, we do not expect the outbreak to cover an area any larger than perhaps a few hundred acres at most based on stand characteristics, past outbreak history of tussock moth on the District, and analysis of current sampling information. Moreover, it is doubtful any outbreak that did occur would extend beyond 2003. The Canyon Creek and Starr Ridge Analysis Areas of the Bear Valley RD were not re-sampled during the Fall cocoon sampling stage due to the low current populations of tussock moth larvae.

Trend indices describe populations in 1999 that are expected to increase an average of 2.1 fold on the Deer Creek Analysis Area, and 1.8 fold on the Fields Creek Analysis Area in 2000 (Table 2). This magnitude of increase would be expected to produce on average, suboutbreak levels of tussock moth in 2000 over these analysis areas.

Table 2. Expected Douglas-fir Tussock Moth Population Density and Trend Indices on Analysis Areas in the Blue Mountains with Populations Predicted to be in Either Outbreak or Suboutbreak in 2000.

Ranger District	Analysis Area	No. Plots Sampled	1999 Early Larval Densities[1]	Predicted 2000 Early Larval Densities[2]	Expected Trend Index[3]	Predicted Population Status in 2000[4]
Prairie City	Phink/Elk	3	0.12	5.57	46.4	Suboutbreak
Prairie City	Wickiup	6	0.13	3.59	27.6	Suboutbreak
Bear Valley	Deer Ck.	5	1.36	2.85	2.1	Suboutbreak
Bear Valley	Fields Ck.	10	3.88	7.02	1.8	Suboutbreak
Pomeroy	Arboth Knott	1	0.40	13.32	33.3	Suboutbreak
Pomeroy	Big Butte LO	1	0.24	26.31	109.6	Moderate Outbreak
Pomeroy	Big Spg. CG	1	0.56	6.83	12.2	Suboutbreak
Pomeroy	Cloverland ski Park	1	0.48	13.32	27.7	Suboutbreak
Pomeroy	Dark Canyon	1	0.08	7.36	92.0	Suboutbreak
Pomeroy	Donaldson Gulch	1	0.08	26.31	328.9	Moderate Outbreak
Pomeroy	Getaway Spg.	1	1.12	13.32	11.9	Suboutbreak
Pomeroy	Meadow Ck. CG	1	0.48	7.36	15.3	Suboutbreak
Pomeroy	Pataha Ck. CG	1	0.32	7.36	23.0	Suboutbreak
Pomeroy	Spangler Trail	1	1.44	58.02	40.3	Severe Outbreak
Pomeroy	Stentz Spg.	1	0.56	13.32	23.8	Suboutbreak
Pomeroy	Sunflower Flat	1	0.40	13.32	33.3	Suboutbreak
Walla Walla	3116 Rd.	1	0.39	3.93	10.1	Suboutbreak
Walla Walla	Bear Canyon/Bear Ck.	2	2.08	8.4	4.0	Suboutbreak

Walla Walla	Brock Meadows	1	3.52	8.4	2.4	Suboutbreak
Walla Walla	Elk Springs Flat	1	4.32	8.4	1.9	Suboutbreak
Walla Walla	Fry Meadows-Orchard	1	1.6	6.11	3.8	Suboutbreak
Walla Walla	Lookout	1	n.s.[5]	13.32	n.a.[6]	Suboutbreak
Walla Walla	Manilla Spg.	1	0.0	26.31	undefined[7]	Moderate Outbreak
Walla Walla	Rocky Bedground	1	0.16	3.88	24.2	Suboutbreak
Walla Walla	Shimmie Horn	1	0.0	3.88	undefined	Suboutbreak
BLM	Hess Road	3	3.04	17.05	5.6	Suboutbreak
BLM	South Lookout	1	1.04	13.32	12.8	Suboutbreak
HCNRA	Upper Imnaha	4	2.48	6.83	2.7	Suboutbreak
ODF-NEO	Cornucopia	3	n.s.	71.13	n.a.	Severe Outbreak
ODF-NEO	East Pine Ck.	3	n.s.	7.46	n.a.	Suboutbreak
ODF-NEO	Schneider Meadows	3	n.s.	341.20	n.a.	Severe Outbreak
Pine	Clear Ck.	24	8.05	34.02	4.2	Moderate Outbreak
Pine	Eagle Ck.	8	0.28	2.66	9.5	Suboutbreak
Pine	East Eagle Ck.	5	20.85	22.26	1.1	Moderate Outbreak
Pine	Little Eagle Ck.	10	14.88	48.41	3.2	Severe Outbreak
Pine	Little Elk Ck.	13	17.79	72.32	4.1	Severe Outbreak
Wallowa Valley	Broad Table	6	0.55	2.44	4.4	Suboutbreak

[1]Mostly instars L1-L2, but some samples may include some L3 and older larvae.
[2]Includes mostly instars L1 and L-2.
[3]Expected Trend Index is the 2000 expected early larval density divided by the 1999 early larval density.
[4]Based on procedures by Mason et al. (1993).
[5]Not sampled during this sampling stage.
[6]Not applicable–cannot be determined.
[7]Undefined, division by zero.

Burns Ranger District

The Burns Ranger District opted not to identify specific areas on the district with critical resource concern; however, they did conduct scaled-back lower crown larval sampling at four locations of previous tussock moth infestation during the Spring 1999 early larval sampling period. These locations included 2850 Rd., High Spot, King Mountain, and Thompson Mountain. The district sampled 8 trees per plot at a total of 21 plots within these four locations. All four analysis areas contained either low or very low population levels (Figure 4).

No 1999 lower crown cocoon data were obtained from any of the Burns Ranger District analysis areas because of the low or very low population levels determined from the early larval sampling. Therefore, we are unable to predict what early larval tussock moth populations on the Burns Ranger District will be in Spring of 2000.

Long Creek Ranger District

The Long Creek Ranger District sampled a total of 10 locations during the Spring 1999 early larval sampling period. These plots represented six general areas of tussock moth host-type having several identified locations within them with resources of concern to the District (see Malheur NF public scoping letter dated July 22, 1999). The six analysis areas are Black Butte, Butte Creek, Cold Canyon, Highway 7, Magone, and Vinegar. Black Butte Analysis Area and one of the Magone plot locations contained low, current early larval tussock moth populations; all the rest had very low current populations of larvae (see Figure 5). Our expectation is for these areas to remain relatively low, or not exceed suboutbreak levels over the course of the tussock moth infestation, based on locations of past outbreaks relative to the Long Creek RD.

Lower crown cocoon sampling was not done on the Long Creek Ranger District analysis areas due to the low, or very low, population levels determined from the early larval sampling. Therefore, we are unable to predict what early larval tussock moth populations on the Long Creek Ranger District will be in Spring of 2000 (see Figure 5).

Prairie City Ranger District

The Prairie City Ranger District sampled a total of 33 locations during the Spring 1999 early larval sampling period. These plots represented seven general areas of tussock moth host-type having several identified locations within them with resources of concern to the District (see Malheur NF public scoping letter dated July 22, 1999). The seven analysis areas included Genesis Project, John Day Headwaters, McCoy, Middle Fork John Day River, Phink/Elk, Reynold, and Wickiup. All areas had low, or very low, currrent early larval populations of tussock moth when sampled in Spring 1999 (Figure 6).

Although the possibility for these plots to reach outbreak levels in 2000 or beyond seems small, it should not be ruled out entirely. Analysis of the 1999 lower crown cocoon data from the Prairie City Ranger District predicts that early larval populations in the Phink/Elk and Wickiup Analysis Areas could be in suboutbreak in Spring of 2000 (Table 2). There is small probability that certain plots locations might contain some levels of visible defoliation in 2000, but these

areas–should they occur–would probably be inconsequential to the overall need for resource protection on the district.

Trend indices describe populations in 1999 that are expected to increase an average of 46.4 fold on the Phink/Elk Analysis Area, and 27.6 fold on the Wickiup Analysis Area in 2000 (Table 2). This magnitude of increase would be expected to produce on average, suboutbreak levels of tussock moth in 2000 over these analysis areas.

Other Prairie City RD analysis area larval populations are predicted to remain at low, or very low, levels in 2000 (see Figure 6). If tussock moth populations on the Prairie City RD did increase to outbreak in 2000, it is doubtful that such an outbreak would be serious or extend beyond 2003. The Genesis Project, John Day Headwaters, Middle Fork John Day River, and Reynold Analysis Areas of the Prairie City RD were not re-sampled during the Fall cocoon sampling stage due to the low current populations of tussock moth larvae.

Umatilla National Forest

The Umatilla National Forest mapped a total of 352,722 acres of tussock moth host-type in "Critical Habitat Areas" (see Umatilla National Forest Douglas-fir Tussock Moth public scoping letter, dated July 28, 1999, on file at the Umatilla NF, Pendleton, OR). Analysis of early larval sampling data for the Umatilla revealed that 7.3 percent of the total larval sampling plots located within critical habitat areas on the Forest were in **suboutbreak** status (little or no visible defoliation) in 1999, 56.3 percent of the plots had **low** populations (no defoliation), and 36.4 percent of the plots contained **very low** populations (see Figure 7).

Analysis of Fall cocoon sampling data for the Umatilla predicted that 1.5 percent of the total cocoon sampling plots located within critical habitat areas on the Forest would be at **severe outbreak** (defoliation intense in upper crowns of many host trees with some trees completely defoliated) in the early larval stages in the Spring of 2000. The analysis further showed that in the critical habitat areas sampled for cocoons in Fall 1999, an additional 4.6 percent of the total cocoon sampling plots would be at **moderate outbreak** (defoliation visible on most host trees) in Spring of 2000, and 27.7 percent of the plots are predicted to be at **suboutbreak**. The remaining 66.2 percent of the plots are predicted to contain **low** populations of larvae (see Figure 8).

<u>Heppner Ranger District</u>

The Heppner Ranger District sampled a total of 4 locations during the Spring 1999 early larval sampling period. These plots, established in tussock moth host-type comprising several areas with resources of critical concern to the District (see Umatilla NF public scoping letter dated July 28, 1999), included Bull Prairie, Mallory Seed Orchard, Snow Park, and Tupper Work Center. All plot locations contained current tussock moth populations that were either low or very low (see Figure 9). Our expectation is for these areas to remain relatively low, and possibly not exceed suboutbreak levels over the course of the tussock moth infestation. The shade-tolerant

Douglas-fir and grand fir components in many of the Heppner RD mixed conifer stands still bear much evidence of the damage from the 1980-1993 western spruce budworm (*Choristoneura occidentalis*) infestation. Some stands, having few seral species, were nearly destroyed by the budworm, or by secondary bark beetle infestations that followed the defoliator outbreak. In these areas, tussock moth habitat is poor, and infestations therein could rapidly lead to starvation of larvae. Hence, these areas are probably not capable of supporting large populations of tussock moth, as opposed to the more healthy mixed conifer areas of the District.

Fall 1999 Lower crown cocoon sampling was also done on the four analysis areas of the Heppner Ranger District, and in additional areas at the 5300.220/750 road junction. Analysis of the cocoon data indicates that in every area, only low populations of early instar tussock moth are predicted to occur in Spring 2000 (Figure 9). This result appears to be consistent with our observation on the condition of many of the host trees on the district, and the low confidence in the host's ability to support large numbers of tussock moth, at least in certain areas.

North Fork John Day Ranger District

The North Fork John Day Ranger District sampled a total of 6 locations during the Spring 1999 early larval sampling period. The plots, established in locations of tussock moth host-type with resources of critical concern to the District (see Umatilla NF public scoping letter dated July 28, 1999), included Lane Creek, Pearson Creek, Fremont Powerhouse, Desolation, Bone Point, and the 53 Rd. Corridor. All plot locations contained very low current tussock moth larval populations (see Figure 10). Our expectation is for these areas to remain low over the course of the tussock moth infestation. Like the Heppner RD, the shade-tolerant Douglas-fir and grand fir components in many of the North Fork John Day RD mixed conifer stands were badly damage during the 1980-1993 western spruce budworm infestation, or by secondary bark beetle infestations that followed the defoliator outbreak. Some of these stands make poor tussock moth habitat, and while infestations may occur, there is likelihood of higher rates of larval mortality from starvation in these areas than in healthier stand locations. Hence, these areas are probably not capable of supporting large populations of tussock moth, as opposed to the more healthy mixed conifer areas of the district.

In addition to conducting lower crown cocoon sampling at the six analysis areas sampled during the spring early larval stage, the district also sampled cocoons on three additional areas in Fall of 1999. These included the Dale compound, Frazier, and Jumpoff Joe analysis areas. Analysis of the cocoon data indicates that in every one of the nine areas, populations of early instar tussock moth are predicted to occur at no higher than low levels in Spring 2000 (Figure 10). As in the case of the Heppner RD, this result appears to be consistent with our observation on the condition of many of the host trees on the district, and low confidence in the residual host's ability to support large numbers of tussock moth, at least in certain areas of the District.

Pomeroy Ranger District

The Pomeroy Ranger District sampled Spring 1999 early larval populations at a total of 20

locations on the district. The plots were established in locations of tussock moth host-type with a diverse array of resources of critical concern to the District (see Umatilla NF public scoping letter dated July 28, 1999). The areas included the following analysis areas: Ables Horse Pasture, Arboth Knott, Big Butte Lookout, Big Spring Campground, Cloverland Ski Park, Dark Canyon, Donaldson Gulch, East Fork Goose Creek, Getaway Springs, Hixson Canyon, Maloney Mountain, Meadow Creek Campground, Pataha Creek Campground, Sheep Creek Falls Campground, Spangler Trail, Stentz Springs Residence, Sunflower flats Three Forks Trail, Wenatchee Trail Head, and Wickiup Campground. All plot locations sampled had low or, very low, current tussock moth larval populations (see Figure 11).

The Pomeroy Ranger District has a history of tussock moth outbreaks, at least back to the 1971-1974 outbreak. Low numbers of tussock moth in all 20 of the areas sampled during the early instars in 1999 seems puzzling given the results of the cocoon sampling conducted from these locations later the same season (see below). It appears likely that sampling, though mostly during the first week in July, was perhaps too early to obtain accurate larval counts. Some crews from both Pomeroy RD and Walla Walla RD recorded comments on data sheets, indicating that sampling might have been a little early at some locations: larvae were quite small (first instar), and some foliage was only just beginning to burst bud during the first week of July. Crews from Walla Walla RD who sampled during the first week in July also reported that new foliage had not flushed at elevations around 4,800 feet, but appeared to have at least partially expanded at most elevations up to 4,000 feet. Sampling too early, before larvae have hatched and dispersed from egg masses, certainly would result in low larval counts. Also, the North ½ of the Umatilla NF may be more strongly influenced by marine air conditions that come through the Columbia River gorge, adding more Temperate Oceanic (Trewartha 1968) climatic conditions that may influence both plant and insect phenology somewhat differently than in other areas of the Blues that are more strongly Temperate Continental in climatic.

Analysis of lower crown cocoon sampling data obtained from these locations in Fall of 1999 yielded some interesting surprises. Cocoon data predicted a severe outbreak in Spring 2000 in the Spangler Trail Analysis Area, and moderate outbreaks in the Big Butte Lookout and Donaldson Gulch Analysis Areas. Almost half of the total number of analysis areas that were sampled for cocoons are predicted to be at suboutbreak levels in the early larval stages next spring. The remaining analysis areas are predicted to have low population levels in 2000 (see Figure 11). It is possible that some of the analysis areas predicted to have suboutbreak populations in 2000 may actually increase to outbreak in 2000. We have seen a 20-fold increase in some areas classified as suboutbreak, from one year to the next, so an abrupt change in population from one year to the next is entirely possible. Hence, it is important to monitor these areas closely in 2000.

One of the problems we see with the Pomeroy RD data set is that only one plot was sampled on each analysis area. This could possible lead to inaccurate predictions of larval densities because populations of tussock moth are often patchy and unequally distributed across the landscape. For very small areas of only a few acres in size, errors associated with estimates based on small samples may not be as great as they would be when small samples are used to estimate

populations over large areas. It would be better to sample at more locations per analysis area in the future.

Trend indices describe populations in 1999 that are expected to increase an average that ranges between 11.9-92.0 fold on the analysis areas predicted to be in suboutbreak in 2000, and range from 40.3-328.9 fold on those analysis areas predicted to be in outbreak in 2000 (Table 2). This magnitude of increase for some of these analysis areas seems to be out of line, and possibly reflects the fact that the early-instar sample upon which the indices are based may have been taken too early, before eclosion from the egg was complete and larvae fully dispersed.

Walla Walla Ranger District

The Walla Walla Ranger District sampled Spring 1999 early larval populations at a total of 26 locations on the district. The plots were established in locations of tussock moth host-type with a diverse array of resources of critical concern to the District (see Umatilla NF public scoping letter dated July 28, 1999). The early larval sampling occurred on the following analysis areas: Spring Mountain (WW01 on Figure 12), Umatilla Fk. Campground (WW02 on Figure 12), Horseshoe (WW03 on Figure 12), Pot Creek (WW04 on Figure 12), Summit Guard Station Plot A (WW05 on Figure 12), Summit Guard Station Plot B (WW06 on Figure 12), Balloon Tree (WW07 on Figure 12), Tollgate (WW08 on Figure 12), Corporation (WW09 on Figure 12), Thomas Creek (WW10 on Figure 12), Rocky Bedground (WW11 on Figure 12), Middle Ridge (WW12 on Figure 12), Shimmiehorn (WW13 on Figure 12), Black Mountain (WW14 on Figure 12), Bobsled (WW15 on Figure 12), Bear Canyon (WW16 on Figure 12), Round Meadows (WW17 on Figure 12), Eden (WW18 on Figure 12), Elk Spring Flats (WW19 on Figure 12), Jubilee (WW20 on Figure 12), Brock Meadows (WW21 on Figure 12), Fry Meadows-Orchard (WW22 on Figure 12), Mottet-Lugar (WW23 on Figure 12), Tiger Plot A (WW24 on Figure 12), Wells (WW25 on Figure 12), Manila Springs (WW27 on Figure 12), and Plot 5 (WW29 on Figure 12). Most plot locations sampled had low or, very low, current tussock moth larval populations (see Figure 12). Bear Canyon, Brock Meadows, Elk Spring Flats, and Horseshoe Analysis Areas all had suboutbreak densities at the time of the 1999 early larval sample.

In addition to sampling cocoons on the areas sampled during the early larval stage, the district also conducted cocoon sampling in the following areas: Tiger Plot B (WW26 on Figure 12), Gibbon (WW28 on Figure 12), Lookout (WW30 on Figure 12), Target Meadow (WW31 on Figure 12), Bear Creek (WW32 on Figure 12), Fox Prairie (WW33 on Figure 12), and Wilber Mountain (WW34 on Figure 12). Of these 30 analysis areas sampled for cocoons, one area (Manilla Springs) had populations high enough that regression analysis predicts this area to have moderate outbreak densities of early instar tussock moth in Spring 2000. About 30 percent of the areas (9 analysis areas) had populations predicted to be suboutbreak in 2000, and the remainder are predicted to have low populations.

The Walla Walla Ranger District, like Pomeroy RD, has had a history of tussock moth outbreaks. The 1971-1974 outbreak caused a considerable amount of tree mortality and topkill on certain areas of the district. Aside from the Manila Springs Analysis Area, there is a good possibility

that one or more other areas of critical resource concern on the Walla Walla RD may experience some level of defoliation during the next season or two given the potential rate of increase in populations from one year to the next which we have seen in other locations; notably on the Pine Ranger District, Wallowa-Whitman NF, both during this outbreak and during the last outbreak in the early 1990's. Our own observations in late September of light defoliation along a stretch of the 6200 Road, in the vicinity of the lookout tower, Elk Spring Flat, and south of Brock Meadows, confirms the cocoon sampling results from these areas, that on the average predict suboutbreak populations for the spring of 2000. It is likely these areas will be in moderate outbreak this spring, and for that reason, bear watching closely.

We see that same problem here on the Walla Walla RD analysis areas as we noted on the Pomeroy RD; i.e., too few sampling locations within each analysis area. More locations within each analysis area should be sampled in the future to provide more reliable estimates of population density.

Trend indices describe populations in 1999 that are expected to increase an average that ranges between 1.9-24.2 fold on the analysis areas predicted to be in suboutbreak in 2000 (Table 2). I could not calculate the trend index for the Manilla Springs Analysis Area, which is predicted to be in outbreak in 2000, because no larvae were found in the early larval sample in 1999.

Wallowa-Whitman National Forest

The Wallowa-Whitman National Forest mapped a total of 241,683 acres of tussock moth host-type in "Critical Habitat Areas" (see Wallowa-Whitman National Forest Douglas-fir Tussock Moth public scoping letter dated July 29, 1999, on file at the Wallowa-Whitman NF, Baker City, OR). Analysis of early larval sampling data for the Wallowa-Whitman revealed that 10.3 percent of the total larval sampling plots located within critical habitat areas on the Forest were currently in **outbreak** status (visible defoliation in tops of trees with some trees–usually small trees–completely defoliated at the beginning of outbreaks) in 1999. Another 28.7 percent of the plots had **suboutbreak** populations (little or no visible defoliation), 43.7 percent had **low** populations (no defoliation), and 17.2 percent of the plots contained **very low** populations of tussock moth (see Figure 13).

Analysis of Fall cocoon sampling data for the Wallowa-Whitman NF predicted that 19.4 percent of the total cocoon sampling plots located within critical habitat areas on the Forest would be at **severe outbreak** (defoliation intense in upper crowns of many host trees with some trees completely defoliated) in the early larval stages in Spring 2000. The analysis of cocoon data also predicted that 9.7 percent of the total plots sampled would be at **moderate outbreak** (defoliation visible on most host trees), 22.3 percent of the plots would be at **suboutbreak**, and 48.5 percent of the plots are predicted to contain **low** populations of larvae (see Figure 14). Essentially all of the analysis areas with plots predicted to be in outbreak in 2000 (nearly 30 percent of the total Forest plots sampled for cocoons) occur on the Pine Ranger District. However, certain locations of critical resource concern on the Wallowa Valley Ranger District and Hells Canyon National

Recreation Area with predicted suboutbreak populations for 2000 may in fact reach outbreak levels in 2000. Hence, these areas bear close watch after tussock moth egg hatch and larval dispersal this coming June.

Baker Ranger District

The Baker Ranger District sampled a total of 9 locations during the spring 1999 early larval sampling period. These plots, established in tussock moth host-type within seven areas with resources of critical concern to the District (see Wallowa-Whitman NF public scoping letter dated July 29, 1999), included Anthony Creek, Baker City Watershed (2 plot locations), Lake Creek, McCully Silver (2 plot locations), North Fork John Day River, Rock Creek, and Upper Powder River. All plot locations contained current tussock moth populations that were very low (see Figure 15). Our expectation is for these areas to remain relatively low, and possibly not exceed suboutbreak levels over the course of the tussock moth infestation. The shade-tolerant Douglas-fir and grand fir components in some of the analysis areas on the Baker Ranger District's mixed conifer stands were damage by defoliation during the 1980-1993 western spruce budworm infestation. A number of these stands may also have varying levels of risk for defoliation by tussock moth, but may not be seriously affected by tussock moth over the course of this current outbreak.

The Baker Ranger District re-sampled the 7 analysis areas during the Fall 1999 Lower crown cocoon sampling stage, but expanded the number of locations within each analysis area to 19 so as to better represent the tussock moth populations in the cocoon stage. Analysis of the cocoon data indicates that low populations of early instar tussock moth are predicted to occur in Spring 2000 (Figure 15). During the last tussock moth outbreak in the Blue Mountains in the early 1990's, and also during the 1970's, outbreak populations of the tussock moth failed to develop on the Baker Ranger District for unknown reasons. It may be that stand characteristics, or other factors in this part of the Forest are such that these areas are less suitable for development of tussock moth outbreaks. Given these results, and lack of past infestation history, we may not see outbreak levels of tussock develop on the Baker Ranger District during this current outbreak cycle.

Hells Canyon National Recreation Area

The Upper Imnaha River area of the Hells Canyon National Recreation Area (NRA) was identified as an analysis area with critical resources of concern (see Wallowa-Whitman NF public scoping letter dated July 29, 1999). Plots were established in four locations in the Upper Imnaha Analysis Area to measure current tussock moth populations in the early instar stage. The analysis of the early instar sampling data found that two of the plots currently have suboutbreak populations and two plots have low populations (see Figure 16).

The same four locations were revisited in the fall of 1999 and sampled for cocoons. Analysis of the cocoon data indicated that 3 of the plots are predicted to be in suboutbreak in Spring 2000, and 1 plot is predicted to be low. The suboutbreak areas included an area located in the SW 1/4

of Sec. 22 (T. 5 S., R. 47 E.), and included Hidden and Evergreen Campgrounds. These areas should be monitored closely next spring in case populations of tussock moth increase to levels higher than the predicted suboutbreak densities (see Figure 16).

During a fall 1999 visit to portions of the Duck Creek area of the NRA (T. 6 S., R. 47 E., Sec. 1) we noted some areas along the 6600 Road that had light defoliation in the tops of host trees. This defoliation was barely visible from the ground and, consequently, probably too light to be visible from the air since no defoliation was mapped in this location during the 1999 aerial insect detection survey. This area, and host-type stands in the vicinity of this defoliation bears watching closely in 2000. Tussock moth populations stand a good chance of increasing to outbreak levels after egg hatch occurs this spring, and close monitoring will help detect any departures from predicted levels, should they occur.

Trend indices describe populations in 1999 that are expected to increase an average of 2.7 fold on the Upper Imnaha Analysis Area (Table 2). This magnitude of increase would be expected to produce on average, suboutbreak levels of tussock moth in 2000 over this analysis area.

La Grande Ranger District

The La Grande Ranger District identified the Flagstaff Analysis Area as an area with critical resource concern (see Wallowa-Whitman NF public scoping letter dated July 29, 1999). The district conducted early larval sampling in the analysis area in Spring 1999, but did not find any tussock moth larvae on the plot that was sampled. Because of the apparent low population levels of tussock moth in this analysis area the district did not conduct Fall 1999 cocoon sampling. We have no basis to make predictions about Spring 2000 population levels without the 1999 cocoon data. However, we don't believe populations will possibly be any higher than suboutbreak in this analysis area in 2000 due to the fact that 1999 populations are very low in this area of the district.

It is noteworthy that portions of the La Grande Ranger District do have historical tussock moth outbreak involvement, at least from the last two tussock moth outbreaks. Review of old aerial insect detection survey data shows that defoliation from tussock moth was mapped on the La Grande RD in 1972 and 1973, and on the old Union Ranger District in 1974. During the 1989-1991 Douglas-fir tussock moth outbreak on the Wallowa-Whitman NF, portions of the Catherine Creek area were defoliated along with many stands on the Pine Ranger District, and were being considered for treatment with the biological insecticide, *Bacillus thuringiensis* (Bt). However, population sampling just prior to scheduled treatment determined that densities were not high enough to meet treatment thresholds and most units were dropped. Some suppression treatment did occur on this portion of the La Grande RD where populations where high enough to treat.

Pine Ranger District

The Pine Ranger District sampled Spring 1999 early larval populations at a total of 61 locations within 5 different analysis areas on the district. The plots were established in locations of tussock moth host-type with a diverse array of resources of critical concern to the District (see

Wallowa-Whitman NF public scoping letter dated July 29, 1999). The areas included the following analysis areas: Clear Creek, Eagle Creek, East Eagle Creek, Little Eagle Creek, and Little Elk Creek. Sampling plot locations had current tussock moth larval populations which ranged from very low to outbreak (see Figure 17). Population status of plots included 9 locations currently in outbreak including 1 plot in Clear Creek, 1 plot in East Eagle, 1 plot in Little Eagle, and 6 plots in Little Elk Analysis Areas; 23 plots in suboutbreak status including 11 plots in Clear Creek, 4 plots in East Eagle, 6 plots in Little Eagle, and 2 plots in Little Elk; and the remaining plots were divided between low and very low population densities (Appendix 1). The 1999 aerial insect detection survey mapped 18,241 acres of defoliation by tussock moth on the Pine Ranger District, which confirms the high levels of tussock moth larvae indicated by the early larval sampling results. The defoliation is distributed across the northern portion of district. The survey mapped 17,256 acres with moderate defoliation, and 985 acres with light defoliation.

The Pine RD re-sampled these analysis areas during the fall 1999 cocoon sampling phase. Analysis of lower crown cocoon sampling data obtained from these locations in Fall of 1999 predicted that 30 of the sampling locations would be in moderate or severe outbreak in 2000. Areas predicted to be in severe or moderate outbreak in Spring 2000 include Clear Creek (13 of 24 plots), Little Elk (8 of 13 plots), Little Eagle (6 of 10 plots), and East Eagle (3 of 5 plots). The Eagle Creek Analysis Area did not have any plot locations predicted for outbreak in 2000 (see Figure 17). Of the total plots sampled, 17 were predicted to be in suboutbreak status in the early larval stage in Spring 2000. It is possible that some of the analysis areas predicted to have suboutbreak populations in 2000, may actually increase to outbreak in 2000. In past outbreaks, we have documented tussock moth populations on the Pine RD having undergone a 20-fold increase from one year to the next in some areas classified as suboutbreak the first year; so an abrupt change in population from one year to the next is entirely possible. If these suboutbreak prediction areas are not included in areas possibly treated to suppress populations to protect the resource this year, then it will be important to continue monitoring these areas closely in 2000.

The population trends illustrated in Figure 17 for 1999 current populations and 2000 predicted populations are remarkably consistent for the analysis areas. Our analysis shows that populations in all areas are predicted to be significantly higher in 2000 than they were in 1999. Trend indices describe populations in 1999 that are expected to increase an average of 9.5 fold on the Eagle Creek Analysis Area, and 1.1 to 4.2 fold on the analysis areas predicted to be in outbreak in 2000 (Table 2). These increases will result in considerable more defoliation on the Pine Ranger District

The Douglas-fir beetle, *Dendroctonus psuedotsugae*, has developed to outbreak levels on the Pine Ranger District, Hells Canyon National Recreation Area, Eagle Cap Ranger Distict, and Wallowa-Valley Ranger District over the past several years (1999 Region 6 aerial insect detection survey; Scott 1998). Trees weakened by tussock moth defoliation will be especially susceptible to bark beetles that are now in great abundance on the north end of the Forest. It is unprecedented to have abnormally high populations of bark beetles like the Douglas-fir beetle present at the beginning of a defoliator outbreak. To my knowledge, we have not had this situation in any of the past tussock moth, or western spruce budworm outbreaks. Bark beetles

typically have built up during, or following defoliator outbreaks, but we have not had them on the "front-end" before. Consequently, we are uncertain as to what effects these interacting agents might ultimately have on host trees. We can certainly expect to see Douglas-fir beetle populations active in stands for probably four more years, in any case. I would not expect these populations to decline until sometime after the tussock moth outbreak collapses and the defoliator-created bark beetle habitat is depleted. The Forest and the Pacific Northwest Research Station have made considerable investment into developing and applying management strategies to control bark beetles on the Pine Ranger District, and these investments should be protected to the extent possible in the coming years.

Unity Ranger District

The Unity Ranger District identified two areas of tussock moth host-type in areas of critical resource concern in 1999. A campground area along Highway 26 containing 776 acres, and the Ironside Analysis Area containing 1,701 acres were identified as being areas with resources of critical concern. However, we received no lower crown early larval or fall cocoon sampling data to evaluate in 1999; hence, we cannot predict population levels for 2000. Based on aerial insect detection survey data, there has not been any tussock moth defoliation recorded for the Unity RD during the past two outbreaks. From this, we can conclude that tussock moth historically (past 4 decades at least) has not been a significant problem to resources on the Unity RD. Perhaps stand conditions or other tussock moth habitat variables in this part of the Forest make the Unity RD less susceptible to outbreaks of tussock moth than in other areas.

Wallowa Valley Ranger District

The Wallowa Valley Ranger District sampled Spring 1999 early larval populations at 13 locations within 3 different analysis areas on the district. The plots were established in locations of tussock moth host-type with a diverse array of resources of critical concern to the District (see Wallowa-Whitman NF public scoping letter dated July 29, 1999). Plots were established in 6 locations of the Broad Table Analysis Area; in 5 locations of the Sheep Creek Analysis Area; and in 2 locations of the Sled Springs Analysis Area to measure current tussock moth populations in the early instar stage. The analysis of the early larval sampling data found that all plots currently have either low or very low populations (see Figure 18).

The same locations were revisited in the fall of 1999 and sampled for cocoons. Analysis of the cocoon data indicated that although the analysis area populations are predicted to increase in 2000, they will still remain at low levels (Figure 18).

The Wallowa Valley Ranger District has a history of tussock moth outbreak in many mixed conifer host stands. During the 1970's outbreak (1972-1974) stands in the northern portion of the Wallowa Mountains received heavy defoliation from tussock moth, and many thousands of trees were killed or damaged to the extent to require salvage and regeneration of many of the sites. These areas were restocked with mostly seral conifer species. During the outbreak years, defoliation was mapped through aerial insect detection surveys, in portions of the Bear Sleds RD

in 1972, the Bear Sleds, Chesnimnus, and Joseph Ranger Districts in 1973, and the same districts, plus areas of the Eagle Caps Wilderness in 1974. The current analysis areas are located in some of the same areas that were hardest hit by tussock moth during the 1971-1974 outbreak, so the low populations predicted for 2000 are somewhat of a puzzle, given past outbreak history.

Since the 1970's outbreak, many former prime tussock moth habitat stands have been brought under new management with emphasis on favoring shade-intolerant seral pines and larch that are not hosts for tussock moth. It is possible that these actions have discouraged tussock moth from developing to outbreaks in recent times due to the changes in stand structure, composition, and stocking, however, this is purely speculation. Nevertheless, it seems prudent to continue to closely monitor these areas over the course of the current outbreak.

Trend indices describe populations in 1999 that are expected to increase an average of 4.4 fold on the Broad Table Analysis Area in 2000 (Table 2). This magnitude of increase would be expected to produce on average, suboutbreak levels of tussock moth in 2000 over this analysis area.

Bureau of Land Management (Baker Resource Area)

The Baker Resource Area, Bureau of Land Management (BLM) is not part of the USDA Forest Service environmental analysis process to analyze proposed alternatives to implement a management strategy to partially control anticipated Douglas-fir tussock moth outbreaks in the Pacific Northwest Region. However, in 1999 the Vale District of the BLM requested that the Blue Mountains Pest Management Service Center help them to evaluate tussock moth populations on two critical resource areas within the Baker Resource Area in northeastern Oregon. One of the resource areas, Hess Road, is located adjacent to, and east of, the Pine Ranger District on the breaks of the Snake River Canyon, a few miles north of Oxbow, Oregon. The second area, southern portion of Lookout Mountain, is located approximately 12 air miles south of Richland, Oregon. This evaluation was to be done following the same protocols the Forest Service used on the Malheur, Umatilla, and Wallowa-Whitman National Forests.

<u>Hess Road Analysis Area</u>

The Hess Road area contains approximately 1,500 acres of tussock moth host-type. The district sampled early stage tussock moth larvae at three plot locations within the analysis area. Analysis of the early larval sampling data for the Baker Resource Area revealed that one-third of the total larval sampling plots located within the Hess Road resource area were currently in **suboutbreak** (little or no visible defoliation), and the remaining two-thirds had **low** (no defoliation) current populations of tussock moth (see Figure 19). The current suboutbreak population densities at Hess Road are just over 5 larvae per 1,000 square inches of foliated midcrown branch tip (Figure 20).

The same sampling locations at Hess Road were revisited again in Fall 1999 to conduct cocoon sampling. Analysis of these data predicted that 33.3 percent of the total cocoon sampling plots located within critical resource areas on the Hess Road Analysis Area would be at **severe**

outbreak (defoliation intense in upper crowns of many host trees with some trees completely defoliated) in the early larval stages in Spring 2000. The analysis of cocoon data also predicted that 66.7 percent of the total plots sampled would have **suboutbreak** populations of larvae in 2000 (see Figure 21). A substantial increase in larval densities are predicted to occur in Spring 2000 on at least one of the Hess Road plots (Figure 20). Densities are expected to increase to an average of 41 larvae per 1,000 square inches of foliage on that single plot. A slight increase in spring larval populations over 1999 larval density levels are predicted to occur in the suboutbreak category in 2000 (Figure 20).

Trend indices describe populations in 1999 that are expected to increase an average of 5.6 fold on the Hess Road Analysis Area in 2000 (Table 2). This magnitude of increase would be expected to produce on average, suboutbreak levels of tussock moth in 2000 over this analysis area.

Lookout Mountain Analysis Area

The south Lookout Mountain area contains approximately 3,200 acres of tussock moth host-type. The Resource Area sampled early stage tussock moth larvae at one plot location within the analysis area. Early larval sampling data for the Baker Resource Area indicate that the tussock moth population is currently at a **low** (no defoliation) level (see Figure 22). The current low population density at the Lookout Mountain sampling location is less than 1 larvae per 1,000 square inches of foliated midcrown branch tip (Figure 20).

The same sampling location at Lookout Mountain was revisited again in Fall 1999 to conduct cocoon sampling. The data predicted that the cocoon sampling plot would continue to be at **low** population levels of tussock moth larvae in 2000 (see Figure 23). An increase in larval densities are predicted to occur in Spring 2000 on the south Lookout Mountain plot. Densities are expected to increase to an average of 13.3 larvae per 1,000 square inches of foliage on that single plot (Figure 20).

Trend indices describe populations in 1999 that are expected to increase an average of 12.8 fold on the South Lookout Analysis Area in 2000 (Table 2). This magnitude of increase would be expected to produce on average, suboutbreak levels of tussock moth in 2000 over this analysis area.

Oregon Department of Forestry (Northeast Oregon Area)

The Northeast Oregon District, Oregon Department of Forestry (ODF) is not part of the USDA Forest Service environmental analysis process to analyze proposed alternatives to implement a management strategy to partially control anticipated Douglas-fir tussock moth outbreaks in the Pacific Northwest Region. However, because certain private forest lands considered at risk to tussock moth are interspersed among the Forest Service lands on the Pine Ranger District that are being analyzed within the Forest Service's 2000 Douglas-fir Tussock environmental analysis, ODF conducted cocoon sampling at three locations to obtain data to predict the status of populations in 2000. The three areas sampled are within, or adjacent to, defoliated areas detected

by the 1999 aerial insect detection survey. The sampling areas include East Pine Creek, Schneider Meadows, and Cornucopia. The Department of Forestry followed essentially the same sampling procedures used by the Forest Service for sampling tussock moth cocoons in 1999 on the Pine RD and elsewhere. In each of the 3 areas, the Department installed 3 cocoon sampling plots consisting of 20 trees per plot. I have included the analysis of the Oregon Department of Forestry cocoon sampling data in this report with the permission of the Oregon Department of Forestry (Salem, Oregon).

Analysis of Fall 1999 cocoon data on private lands predicted outbreaks in 2 of the 3 areas sampled for 2000 (Figure 24). Tussock moth populations at both Cornucopia and Schneider Meadows are predicted to be in **severe outbreak** (defoliation intense in upper crowns of many host trees with some trees completely defoliated) in the early larval stages in the spring of 2000. Mean early larval densities at Cornucopia and Schneider Meadows are predicted to average 71 and 341 larvae per 1,000 square inches of foliated branch, respectively, in Spring 2000. Analysis of the data from private lands also predicts that 2 of the plots at East Pine Creek will be in suboutbreak, with early larval densities averaging about 10 larvae per 1,000 square inches of foliated branch in Spring 2000, and the third plot at East Pine Creek will contain low-density populations of tussock moth. These results are consistent with population predictions for the four Forest Service cocoon-sampled plots nearest to the private land plots (i.e., Clear Creek Plots 4, 5, 6, and 7).

Summary and Recommendations

The current outbreak cycle of the Douglas-fir tussock moth is just beginning in the Pacific Northwest Region. The Blue Mountains of northeastern Oregon and southeastern Washington are the only areas of the Region to have visible tussock moth defoliation mapped during the 1999 aerial insect detection survey. The first defoliation of the current outbreak was mapped on the Wallowa-Whitman National Forest in 1999, and consisted of a total of 18,241 acres on the Pine Ranger District, 2,742 acres on the Hells Canyon National Recreation Area, and 88 acres on interspersed private timber lands. Additional acres are expected to be defoliated on the Pine RD and HCNRA. It is expected that some defoliation may also occur on the areas of predicted outbreak on the Walla Walla RD, Pomeroy RD, and perhaps a minor amount on the Bear Valley RD and elsewhere in the Blue Mountains in 2000. It is anticipated that this current outbreak could last through 2003 before it collapses.

Generally, it is common for tussock moth populations to increase to outbreak over a region or sub-region like the Blue Mountains in a relatively synchronous fashion. However, we have noted that the early 1990's tussock moth outbreak in the Blue Mountains was somewhat less synchronized in timing in different localities of the Blue Mountains. For example, the infestations on the Burns Ranger District were out of synch by a year or two from the Pine Ranger District outbreak. This tussock moth outbreak started on the Pine Ranger District in 1990, and much of the outbreak area on the Pine RD was suppressed with treatments of the microbial insecticide, Bacillus thuringiensis, in 1991. In untreated areas of the Wallowa-Whitman NF, tussock moth defoliation continued to occur through 1992, with 1,699 acres being

aerially mapped on private lands that year. These untreated populations within the Wallowa-Whitman NF eventually collapsed on their own by the end of the 1992 season. However, the outbreak at Burns RD was really just getting started at this time. Both early larval sampling of the Burns RD populations (Mason et al. 1998), and defoliation mapped in the aerial insect detection survey in 1992 (aerial survey map on file in Pacific Northwest Regional Office, Portland, OR) indicated increasing populations of tussock moth. The Burns tussock moth outbreak continued to cause defoliation which was aerially sketch-mapped each year, and larval densities were estimated by lower crown early larval sampling, through 1995. The Burns tussock moth populations finally collapsed in 1995 from a number of natural causes including nucleopolyhedrosis virus-caused disease, insect parasitoids, and probably starvation, predation, and other unknown causes.

Given the asynchronous outbreak trends of the Burns Ranger District during the early- to mid-1990's, it seems plausible that the current outbreak could display similar asynchrony over different portions of the Blue Mountains, and possibly over the Region. Accordingly, annual population monitoring in addition to pheromone trapping is advisable throughout the course of this outbreak. In general, it is recommended that all federal administrative units in the Blue Mountains continue to monitor tussock moth populations in 2000 on all analysis areas with identified critical resource concerns. This includes both lower crown early larval sampling in the spring, and lower crown cocoon sampling in the fall. Presuppression sampling funds for the Blue Mountains Forests to sample tussock moth populations in 2000 have been requested for each Forest from the Regional Office. The Pacific Northwest Region is committed to providing suppression funds for this purpose as long as these funds are approved and available from the Washington Office Forest Health Protection Staff, State and Private Forestry.

The results of the analysis of 1999 tussock moth cocoon samples from the Blue Mountains identified several analysis areas that are predicted to either be in outbreak in 2000, or have suboutbreak population levels. The latter areas could be in outbreak the following year (2001) if populations continue to increase; thus it is especially important to continue monitoring areas with suboutbreak populations. In general, since outbreak population densities could lead to unacceptable resource damage of the identified areas with critical resource concern, I recommend the treatment with an aerial application of a biological insecticide registered for tussock moth, of those areas having predicted outbreak populations in 2000 if those areas develop to outbreak. Treatment of outbreaks is necessary to partially suppress populations to protect valuable resources and reduce the level of defoliation damage to host trees in those areas identified with resources of critical concern to the Forests.

When all cocoon data for individual analysis areas are analyzed as a whole, several analysis areas on the Umatilla and Wallowa-Whitman National Forests stand out as having predicted outbreaks of tussock moth in 2000. No analysis area, as a whole, is predicted to be in outbreak in 2000 on the Malheur National Forest, although 1 plot out of the 10 sampled on the Fields Creek Analysis Area was predicted to have outbreak population levels in 2000. Population data taken on the Wallowa-Whitman National Forest indicated that tussock moth would be in outbreak only on the Pine Ranger District, and not on any other District on that Forest. Likewise, cocoon data

obtained from analysis areas on the Umatilla National Forest indicated that tussock moth populations are expected to be in outbreak on both the Pomeroy and Walla Walla Ranger District, but not on the Heppner nor North Fork John Day Ranger Districts. However, based on the limited sample size for data collected on the Pomeroy and Walla Walla Ranger Districts I have reservations about making firm recommendations to treat predicted outbreak populations on certain analysis units on those Districts in 2000. Those concerns will be addressed in the following paragraphs.

Pest management recommendations for areas with predicted outbreak and suboutbreak populations in 2000 are listed in Table 3. Analysis areas that had one or more plots with predicted outbreak level populations for 2000 include the following: Fields Creek Analysis Area (Bear Valley RD, Malheur NF); Spangler Trail Analysis Area, Big Butte Lookout Analysis Area, and Donaldson Gulch Analysis Area (Pomeroy RD, Umatilla NF); Manilla Spring Analysis Area (Walla Walla RD, Umatilla NF); Clear Creek Analysis Area, East Eagle Creek Analysis Area, Little Eagle Creek Analysis Area, and Little Elk Creek Analysis Area (Pine RD, Wallowa-Whitman NF); and Hess Road Analysis Area (Baker Resource Area, Vale District, BLM). Locality maps showing sampling locations for analysis areas predicted with outbreak populations of tussock moth are given in Figures 25-32. It should be noted that some of the sampling locations may not correspond exactly with the analysis area that they represent due to certain requirements for lower crown host tree branching and foliage conditions of sample trees. In some cases, trees nearby–usually within 1/4 mile of the analysis area–had to be sampled because suitable lower crown sampling trees could not be found within the boundaries of the analysis area. To facilitate sampling representative lower crown larval and cocoon populations, we made the assumption that the relatively close proximity of surrogate sample trees to the actual analysis area would contain similar populations of tussock moth as on host trees of the analysis area. However, we did not validate this assumption due to limitations of time and resources to conduct such a validation study.

Certain areas like the Fields Creek Analysis Area contain resource concerns that are not at risk to tussock moth because they are non-host areas (like the Cedar Grove Natural Area in this case), but may be interspersed with tussock moth host trees or surrounded by mixed conifer stands containing host components having varying degrees of susceptibility to tussock moth defoliation. The Fields Creek Analysis Area is also an interesting case in regard to whether or not the majority of the area actually contains substantive vulnerability to tussock moth defoliation damage and merits treatment, even though outbreak populations are predicted for 2000 in this analysis area. It was noted in Table 2 that when all 10 sample plots in the analysis area are averaged, the cocoon data actually predicts populations in 2000 to be in suboutbreak, but a certain stand, or stands, represented by 1 of the 10 cocoon sampling plots will be in outbreak. The stands most likely to host development of a tussock moth outbreak in the Fields Creek Analysis Area seem to be that portion of the same 150 or 200 acres of heavily defoliated area that was not salvaged after the tussock moth defoliation of 1991 and 1992. An assessment of this outbreak in 1992 found that although populations of tussock moth could be found over a larger area near Fields Peak, only about 140 acres were heavily damaged by defoliation, with some patches containing trees 40 to 70 percent defoliated (Scott and Schmitt 1994). This population

also declined quickly on its own because of high rates of larval and pupal parasitism, and natural build up of nucleopolyhedrosis virus in the population. Salvage and thinning that occurred in these stands after the outbreak may have reduced the future susceptibility to infestation and vulnerability to damage by tussock moth. An old-growth stand lies east of and adjacent to the harvest unit areas damaged by tussock moth; this is one of the critical resource concerns in this analysis area. Risk to tussock moth, however, is considered moderate and the area is limited in size; thus restricting the size of any potential outbreak in this area. Shrub land and grass land bound the old-growth area on the north and east, the harvest units (treated during the last tussock moth outbreak) lie to the west, and the southern side is bounded by a ponderosa pine-dominated mixed conifer stand containing occasional small white fir and Douglas-fir in-growth in the understory. Although other factors may be considered and analyzed, it is likely that if an outbreak develops here, it will neither be widespread nor damaging, nor justify need for treatment. For this area, since damage from tussock moth may be limited and short-lived given past outbreak history and current stand conditions of formerly "high-risk" areas treated after the last outbreak, it may be prudent to simply monitor larval and cocoon populations through the 2000 season, and defer any actual treatment until 2001 if warranted at that time.

Table 3. Douglas-fir Tussock Moth Suppression and Monitoring Recommendations for Analysis Areas in the Blue Mountains with Populations Predicted to be in Either Outbreak or Suboutbreak in 2000.

FOREST	DISTRICT	ANALYSIS AREA	RECOMMENDATION	
			Suppression	Monitor/ Suppress
Malheur	Bear Valley	Fields Creek		Suppress only in high-risk stands if outbreak develops or continues as predicted/or continue monitoring in 2000 with potential treatment in 2001 if outbreak continues.
Malheur	Prairie City	Phink/Elk Wickiup		Monitor populations in 2000. Consider suppression of outbreak in 2001 if predicted by Fall cocoon sampling in 2000.

Umatilla	Pomeroy	Spangler Trail Big Butte Lookout Donaldson Gulch	Suppress only if outbreak develops as predicted in 2000. **<u>Additional cocoon sampling on multiple plots of each analysis area before May 2000, and intensive early larval monitoring on multiple plots of each analysis area upon egg hatch in June 2000, are strongly recommended because the predictions of outbreak were based upon data from only one plot per analysis area.</u>**	
Umatilla	Pomeroy	Cloverland Ski Park Dark Canyon Getaway Spring Big Spring C.G. Sunflower Flat Stentz Spr. Residence Arboth Knott Pataha Creek C. G. Meadow Creek C. G.		Monitor populations in 2000. Consider suppression of outbreak in 2001 if predicted by Fall cocoon sampling in 2000.
Umatilla	Walla Walla	3116 Road Rocky Bedground Shimmiehorn Bear Creek Bear Canyon Elk Flat Brock Meadows Fry Meadows Orchard Lookout Mountain		Monitor populations in 2000. Consider suppression of outbreak in 2001 if predicted by Fall cocoon sampling in 2000.

Umatilla	Walla Walla	Manilla Spring	Suppress only if outbreak develops as predicted in 2000. **Additional cocoon sampling on multiple plots of each analysis area before May 2000, and intensive early larval monitoring on multiple plots of each analysis area upon egg hatch in June 2000, are strongly recommended because the predictions of outbreak were based upon data from only one plot per analysis area.**	
Wallowa-Whitman	HCNRA	Upper Imnaha Recreation Sites		Monitor populations in 2000. Consider suppression of outbreak in 2001 if predicted by Fall cocoon sampling in 2000.
Wallowa-Whitman	Pine	Clear Creek East Eagle Ck. Little Eagle Ck. Little Elk Ck.	Suppress if outbreak develops or continues as predicted	
Wallowa-Whitman	Pine	Eagle Creek		Monitor populations in 2000. Consider suppression of outbreak in 2001 if predicted by Fall cocoon sampling in 2000.

Wallowa-Whitman	Wallowa Valley	Broad Table Sheep Creek Sled Springs		Monitor populations in 2000. Consider suppression of outbreak in 2001 if predicted by Fall cocoon sampling in 2000.
Bureau of Land Management	Baker Resource Area	Hess Road		Suppress only in high-risk stands if outbreak develops or continues as predicted/or continue monitoring in 2000 with potential treatment in 2001 if outbreak continues.
Bureau of Land Management	Baker Resource Area	South Lookout Mountain		Monitor populations in 2000. Consider suppression of outbreak in 2001 if predicted by Fall cocoon sampling in 2000.

Similarly, tussock moth on a small portion of the Hess Road Analysis Area is predicted to be in outbreak in 2000, but this area may not merit treatment for several reasons: (1) the data on which the predicted outbreak populations of tussock moth are based were taken from one plot that represents only a very small area (approximately 20-40 acres), and when all three plots are averaged the cocoon data predicts only suboutbreak populations overall (see Table 2); (2) within a landscape context, this area borders a portion of the Hells Canyon National Recreation Area which is not recommended for treatment because of predicted low densities on plots nearest this site, and treatment of such a small site is ill-advised when adjacent lands are not also being treated which would help to form a larger contiguous treatment area that could be justified both biologically and economically; and (3) this site represents neither high nor critical resource value in terms of visual or recreation resources. Given these factors, the Hess Road Analysis Area does not warrant treatment this year. I recommend re-sampling of early larval and cocoon stages on the Hess Road Analysis Area in 2000, even though a portion of the area is predicted to have outbreak populations of tussock moth this year.

The Pine Ranger District had outbreak populations of tussock moth in 1999 that caused visible defoliation in or near sampling plots of all five analysis areas. Furthermore, analysis of 1999 cocoon data yielded outbreak predictions on plots in all analysis areas but Eagle Creek (Table 2).

Accordingly, I recommend treatment to partially suppress tussock moth populations and minimize resource damage in the Clear Creek, East Eagle Creek, Little Eagle Creek and Little Elk Creek Analysis Areas, and continued lower crown early larval and fall cocoon sampling in the Eagle Creek Analysis Area in 2000. Given that Douglas-fir beetle is already in outbreak on the Pine Ranger District and other northern Districts of the Wallowa-Whitman NF, it is especially crucial to treat tussock moth populations to prevent further weakening of Douglas-firs in order to continue to slow the expansion of bark beetle populations and protect high investments already made into the prevention and suppression of Douglas-fir beetle populations on the Pine Ranger District in 1999. Efforts will continue to prevent and suppress bark beetles on the Pine Ranger District in 2000 to preserve and protect existing stands of old-growth and late and old structure. I believe the Douglas-fir tussock moth suppression treatments will indirectly aid in the management of Douglas-fir beetle on the District by minimizing defoliation-weakened trees in critical resource areas containing mature, large-diameter components of Douglas-fir. In addition, the 1999 aerial insect detection sketch map indicates populations of fir engraver, *Scolytus ventralis*, are on the increase. Tussock moth defoliation, unabated, will undoubtedly lead to increased activity by these bark beetles in defoliation-weakened true firs. Tussock moth treatments will also help prevent post-defoliation buildup of these beetles in critical resource areas.

Both the Pomeroy and Walla Walla Ranger Districts identified numerous analysis areas with critical resource concerns, but sampled only 1 cocoon plot of 20 trees on the Pomeroy RD analysis areas, and 1 cocoon plot of 50 or 51 trees on each of the Walla Walla RD analysis areas. Analyses of the data from plots representing the Spangler Trail, Big Butte Lookout, and Donaldson Gulch Analysis Areas on the Pomeroy RD, and the Manilla Springs Analysis Area on the Walla Walla RD all predicted outbreak populations in 2000 on these areas; yet, because the single plot sample of each area prohibited a multistage analysis of the densities to estimate between plot variability in densities, I do not have strong confidence in the estimated means.

Tussock moth populations can be variable over an area, and the resultant defoliation patchy. A single sample plot of 20-50 trees spread over a couple of acres does not allow one to determine with any degree of confidence the variability in distribution and density of future larval populations over a larger landscape that encompasses the analysis area, using the forecasting procedure available to us. Therefore, I qualify the recommendation to treat these predicted outbreak analysis areas only after additional multiple plot sampling occur in each of the analysis areas, and concur with the initial findings that these areas, indeed, have a high probability of being in outbreak in 2000. Larval sampling in the spring, though advisable, may not allow a sufficient window of time to acquire and analyze data, and prepare, order, and apply a timely treatment unless the application team is already on site, or can quickly relocate operations to apply treatment at the appropriate time of insect development to achieve expected results. I would advise the Pomeroy and Walla Walla Ranger Districts to make an effort to collect additional cocoon data from several more plots in each analysis area this winter, as access allows, so that further analysis of data may validate the initial findings based on single-plot data. I also recommend the continued re-sampling of all other analysis areas on these Districts.

Some analysis areas that are predicted to average suboutbreak populations of tussock moth in 2000 may actually increase to outbreak levels, or small defoliation patches may appear within areas predicted to be in suboutbreak. This is not unexpected given the typical patchy nature of defoliation caused by tussock moth. It is especially important in 2000 to re-sample the early larval and cocoon stages of tussock moth in those analysis areas predicted to be in suboutbreak. These areas could easily increase to outbreak in 2001. The Spring early larval sampling will provide information about the current status of tussock moth, and Fall cocoon samples will enable us to predict the status of populations next Spring (2001) in the early larval stage. For this reason I recommend re-sampling not only these suboutbreak-predicted analysis areas, but all analysis areas in 2000 including the areas with predicted low populations.

Literature Cited

Clendenen, G.; V. F. Gallucci; R. I. Gara. 1978. On the spectral analysis of cyclical tussock moth epidemics and corresponding climatic indices, with a critical discussion of the underlying hypothesis, pp. 279-293. *In* H. H. Shugart, ed., Proc. Institute for Mathematics and Society, Conference on time series and ecological processes. Denver, CO.

Daterman, G. E.; R. L. Livingston; J. M. Wenz; L. L. Sower. 1979. How to use pheromone traps to determine outbreak potential. Agric. Handb. 546. Washington, DC: U. S. Department of Agriculture, Forest Service. 11 p.

Harris, J. W. E.; A. F. Dawson; R. G. Brown. 1985. The Douglas-fir tussock moth in British Columbia 1916-1984. Report BC-X-268. Victoria, B. C.: Canadian Forest Service, Pacific Forestry Research Centre.

Martignoni, M. E. 1999. History of TM BioControl-1: the first registered virus-based product for control of a forest insect. American Entomologist (45): 30-37.

Mason, R. R. 1977a. Sampling low density populations of the Douglas-fir tussock moth by frequency of occurrence in the lower tree crown. Res. Pap. PNW-216. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 8 p.

Mason, R. R. 1977b. Advances in understanding population dynamics of the Douglas-fir tussock moth. Bull. Entomol. Soc. Am. 23(3): 168-171.

Mason, R. R. 1992. Populations of arboreal spiders (Araneae) on Douglas-firs and true firs in the Interior Pacific Northwest. Environ. Entomol. 21(1): 75-80.

Mason, R. R.; H. G. Paul. 1994. Monitoring larval populations of the Douglas-fir tussock moth and western spruce budworm on permanent plots: sampling methods and statistical properties of data. Gen. Tech. Rep. PNW-GTR-333. Portland, OR: U. S. Department of

Agriculture, Forest Service, Pacific Northwest Research Station, 22 p.

Mason, R. R.; D. W. Scott; M. D. Loewen; H. G. Paul. 1998. Recurrent outbreak of the Douglas-fir tussock moth in the Malheur National Forest: a case history. Gen. Tech. Rep. PNW-GTR-402. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 14 p.

Mason, R. R.; D. W. Scott; H. G. Paul. 1993. Forecasting outbreaks of the Douglas-fir tussock moth from lower crown cocoon samples. Res. Pap. PNW-RP-460. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 12 p.

Mason, R. R.; B. E. Wickman. 1988. The Douglas-fir tussock moth in the Interior Pacific Northwest, pp. 179-209 *In* A. A. Berryman, ed., Dynamics of forest insect populations: patterns, causes, implications. Plenum Press, New York, NY.

Ragenovich, Iral. 1998. 1998 Douglas-fir tussock moth Early Warning System trapping summary for Oregon and Washington. Unnumbered Report. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Region, Natural Resources, Forest Insects and Diseases. 7 p. + appendices.

Ragenovich, Iral. 1999. Douglas-fir tussock moth cocoon sampling procedure–Fall 1999. Unnumbered Report. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Region, Natural Resources, Forest Insects and Diseases. 3 p. + appendices.

Scott, Donald W. 1998. Review of 1998 Douglas-fir beetle infestations on the Pine Ranger District and Hells Canyon National Recreation Area, Wallowa-Whitman National Forest. Report No. BMZ-99-1. La Grande, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Region, Wallowa-Whitman National Forest, Blue Mountains Pest Management Zone. 21 p.

Scott, Donald W. ; Craig L. Schmitt. 1994. Insect and disease conditions on National Forest lands
in the Blue Mountains 1990-1993. Report No. BMZ-94-11. La Grande, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Region, Wallowa-Whitman National Forest, Blue Mountains Pest Management Zone. 34 p.

Scott, Donald W.; Craig L. Schmitt. 1996. Forest health on National Forest lands in the Blue Mountains 1990-1996: insects and diseases. Report No. BMZ-96-12. La Grande, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Region, Wallowa-Whitman National Forest, Blue Mountains Pest Management Zone. 42 p.

Sheehan, K. A.; E. A. Willhite; A. Eglitis; P. Flanagan; T. F. Gregg; B. B. Hostetler. 1993. Regional guidelines for sampling Douglas-fir tussock moth and western spruce budworm.

Report No. R6-93-03. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Region. 18 p.

Shepherd, R. F.; D. D. Bennett; J. W. Dale; S. Tunnock; R. E. Dolph, Jr.; R. W. Thier. 1988. Evidence of synchronized cycles in outbreak patterns of Douglas-fir tussock moth, *Orgyia pseudotusgata* (McDunnough) (Lepidoptera: Lymantriidae). Memoirs Entomological Society of Canada. 146: 107-121.

Swetnam, Thomas, W.; Boyd E. Wickman; Gene H. Paul; Christopher H. Baisan. 1995. Historical
patterns of western spruce budworm and Douglas-fir tussock moth outbreaks in the northern Blue Mountains, Oregon, since A.D. 1700. Res. Pap. PNW-RP-484. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 27 p.

Thompson, C. G. 1978. Nuclear polyhedrosis epizootiology. In: Brookes, Martha H.; R. W. Stark; Robert W. Campbell, eds. The Douglas-fir tussock moth: A synthesis. Tech. Bull. 1585. Washington, D.C.: U. S. Department of Agriculture, Forest Service, Science and Education Agency: 136-140. Chapter 7.

Thompson, C. G.; Bohdan Maksymiuk. 1978. Laboratory and simulated field tests. In: Brookes, Martha H.; R. W. Stark; Robert W. Campbell, eds. The Douglas-fir tussock moth: A synthesis. Tech. Bull. 1585. Washington, D.C.: U. S. Department of Agriculture, Forest Service, Science and Education Agency: 147-149. Chapter 7.

Trewartha, G. T. 1968. An introduction to climate. McGraw-Hill, New York, New York. 408 p.

USDA. 1996. Forest health update: five years later – monitoring report to the Forest Supervisor, Wallowa-Whitman National Forest. Unnumbered report. Baker City, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Region, Wallowa-Whitman National Forest. [Unconventional pagination].

Wickman, Boyd E.; Richard R. Mason; C. G. Thompson. 1973. Major outbreaks of the Douglas-fir tussock moth in Oregon and California. Gen. Tech. Rep. PNW-5. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 18 p.

Wright, L. C.; A. A. Berryman; B. E. Wickman. 1984. Abundance of the fir engraver, *Scolytus Ventralis*, and the Douglas-fir beetle, *Dendroctonus pseudotsugae*, following tree defoliation by the Douglas-fir tussock moth, *Orgyia pseudotsugata*. Can. Ent. 116: 293-305.